Boeing CLEEN Phase III Program Update

FAA CLEEN Consortium – Industry Day

Jennifer Kolden

May 8, 2024

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Boeing Program
CLEEN Phase III

NextGEN CLEEN

Quiet High-Lift

"Reducing Airframe Noise"

"Enabling Quieter, Advanced Propulsion"

Quiet Landing Gear

Next Generation Inlet

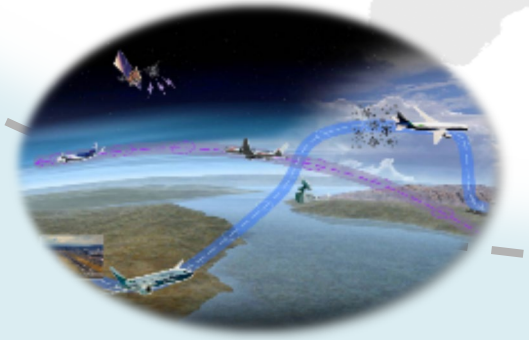
737 MAX

eco Demonstrator PROGRAM

787

"Improving How the Airplane is Operated"

Intelligent Operations



Sustainable Aviation Fuels

"Accelerating SAF Uptake to meet CO2 goals"

Aurora Flight Sciences, A Boeing Company

BOEING

NASA

UDRI University of Dayton Research Institute

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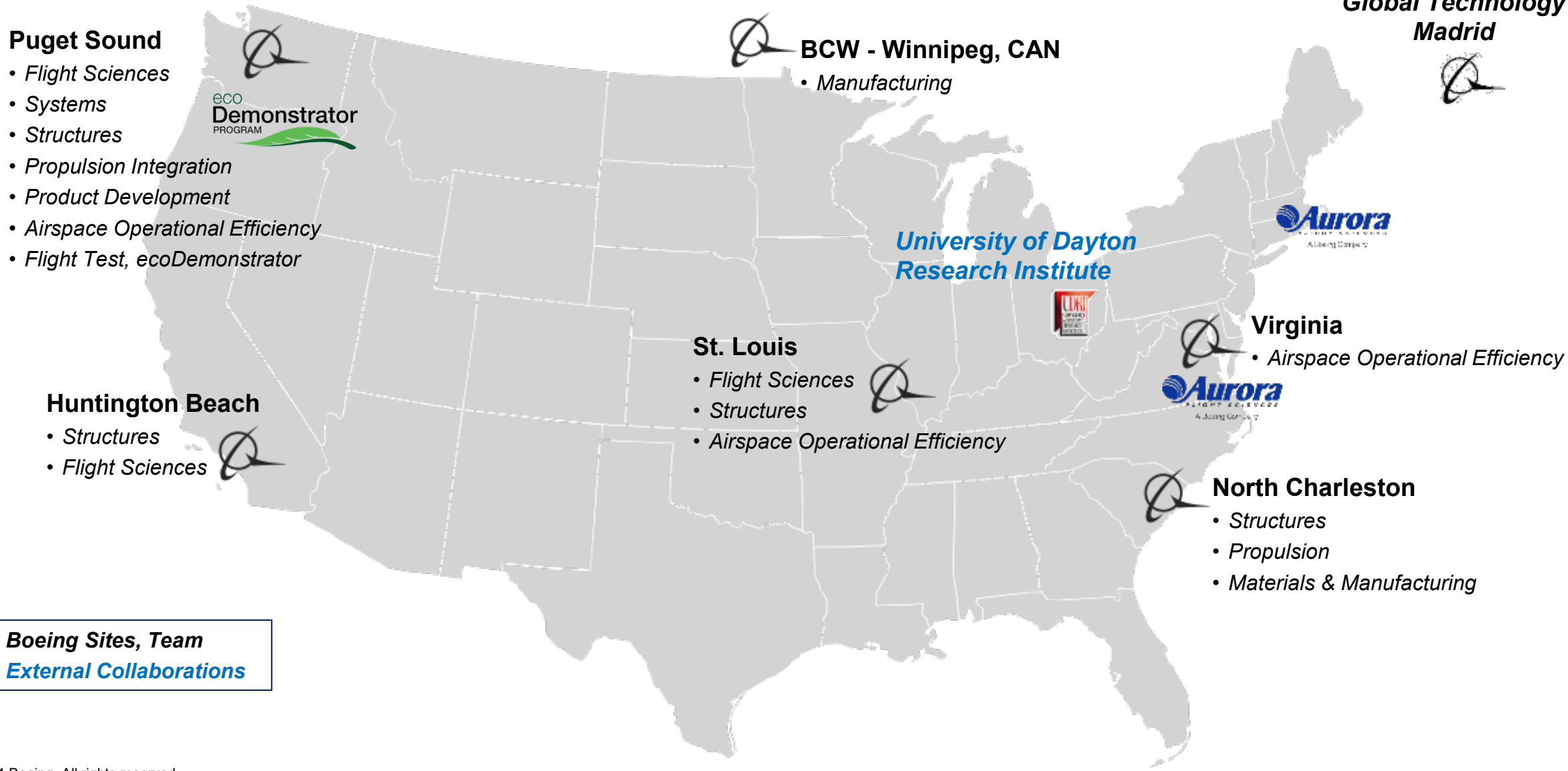
Program Team – “Best of Boeing”



Puget Sound
- *Flight Sciences*
- *Systems*
- *Structures*
- *Propulsion Integration*
- *Product Development*
- *Airspace Operational Efficiency*
- *Flight Test, ecoDemonstrator*

BCW - Winnipeg, CAN
- *Manufacturing*

Global Technology Madrid

University of Dayton Research Institute

Virginia
- *Airspace Operational Efficiency*

St. Louis
- *Flight Sciences*
- *Structures*
- *Airspace Operational Efficiency*

Huntington Beach
- *Structures*
- *Flight Sciences*

North Charleston
- *Structures*
- *Propulsion*
- *Materials & Manufacturing*

- ***Boeing Sites, Team***
- ***External Collaborations***

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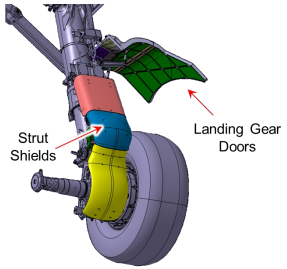
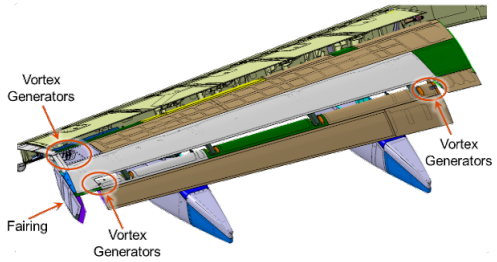
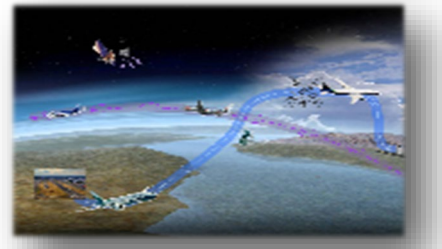
Projects & Benefits

	Quiet Landing Gear	Quiet High-Lift	Next Generation Inlet	Intelligent Operations	Sustainable Aviation Fuels
Technology					
	• Acoustically Treated Main Gear Doors • Perforated Strut Shields	• Outboard Flap Side Edge Fairings • Outboard Flap Vortex Generators	• New Structural Architecture • New Ice Protection System • Maximize Acoustic Treated Area	• Noise-Optimized Flight Paths • Leverages Existing Capabilities	• Higher Performing Blends • Drop-in Compatibility • Support Scale-up
Impact	Reduce Community Noise	Reduce Community Noise	Enable New Engines, Reduce Community Noise, Fuel Burn	Reduce Community Noise, Fuel Burn	Reduce Fuel Burn, Emissions
Benefits / Metrics	Up to 0.5 EPNdB	Up to 0.5 EPNdB	1.5 EPNdB 2.0% Block Fuel	3-5 peak dBA 2% Take-off Block Fuel 5% Approach Block Fuel	2%-3% Block Fuel
Projected Fleet Impact	Reduce 65 dB community noise contours	Reduce 65 dB community noise contours	Community Noise, 82M Metric ton, CO2 reduction	Community Noise, 28M Metric ton, CO2 reduction	2950M Metric ton, CO2 reduction
Transition	2030 , 2035 Retrofit	2030 , 2035 Retrofit	2030 (partial) , 2035	2030 , 2035 Retrofit	2030 , 2035 Retrofit

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Technology Transition

- Boeing Product Development leveraging CLEEN III technologies
  - New Products and Retrofit
  - Acoustic lining designs
  - Low speed / high lift configuration
  - Nacelle acoustics and ice protection approach
  - Advanced lower noise landing gear and flap systems
- Advancing/Refining/Validating noise prediction tools and design practices
- Near-term capabilities/services aligned with FAA NextGen and DataComm
- Maturing fuel system component readiness to enable low aromatic fuels – SAF compatibility

CLEEN Phase III Technologies aligned with Product Strategies and Sustainability Vision

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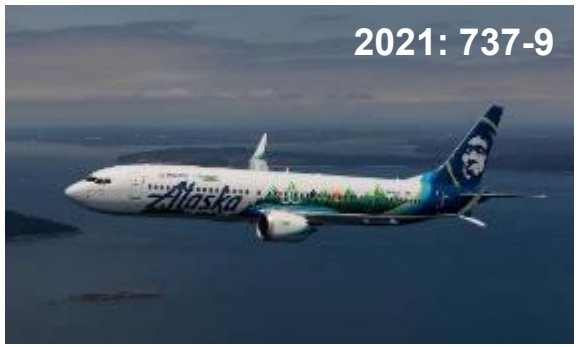
EcoDemonstrator Program History ~ 250 projects



eco Demonstrator PROGRAM

CLEEN Phase III Program leverages successfully proven ecoDemonstrator Program

Program Summary – 737 ecoDemonstrator

ATP

Today

737 & 787 Flight Demos

Final Report

- Quiet Landing Gear
- Quiet High Lift
- Intelligent Operations

eco Demonstrator PROGRAM

Design | Fab / Assembly | Flight | Analysis / Reporting

- Next Generation Inlet
- Intelligent Operations

eco Demonstrator PROGRAM

Design | Fab / Assembly | Flight | Analysis / Reporting

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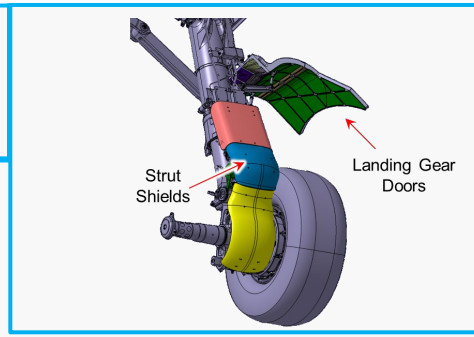
Quiet Landing Gear (QLG)

Objective: Develop landing gear (airframe) technologies to reduce aircraft noise at approach

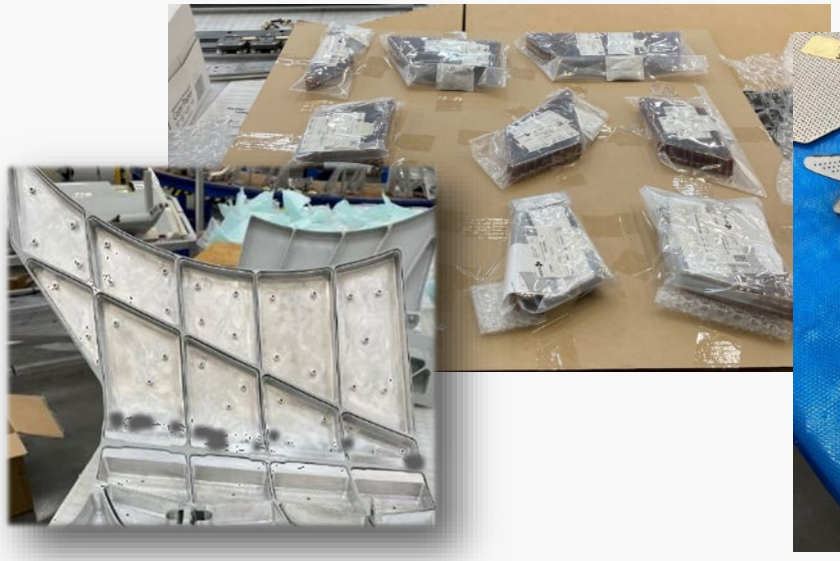


Recent Accomplishments:

(Nov – May)

Conceptual Design → Preliminary Design → Detailed Design → **Fabrication Assembly** → Flight Testing → Reporting

Landing Gear Shields



Door pocket inserts and Acoustic core

Acoustic Face Sheet

New Phased Array

Lookahead:

Complete Fabrication & Assembly
Flight Testing

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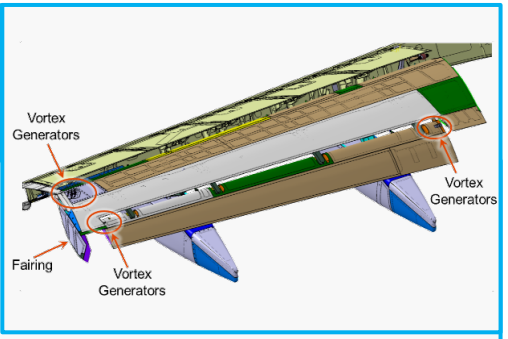
Quiet High Lift (QHL)

Objective: Develop outboard flap (airframe) technologies to reduce aircraft noise at approach



Recent Accomplishments:

(Nov – May)

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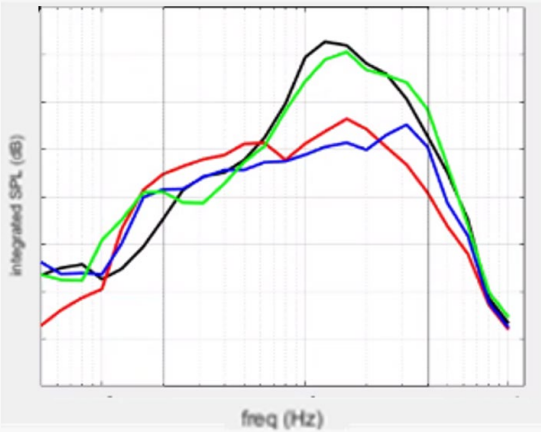
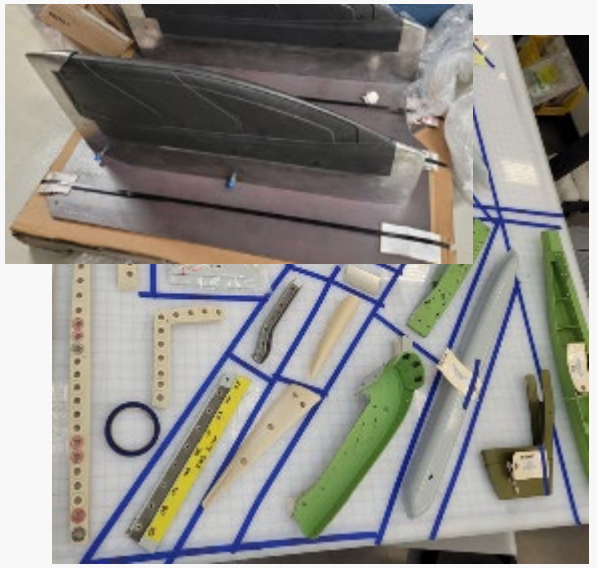


CFD/CAA
Pre-Test Predictions Complete

Controlled VG's (SMA)



Fairing Components

Fixed and Spring-Loaded VGs

Lookahead:

Complete Fabrication & Assembly
Flight Testing

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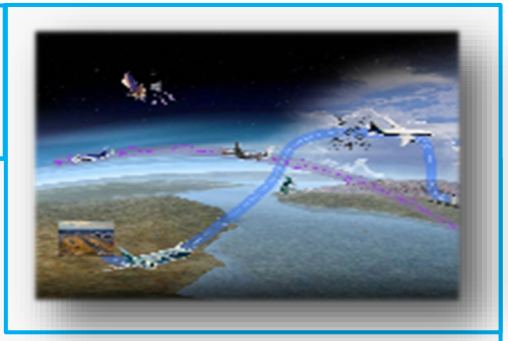
Intelligent Operations (IO)

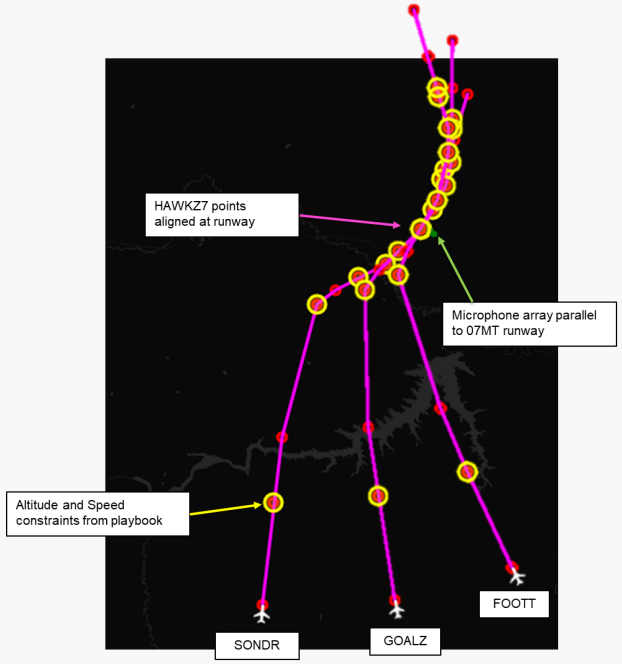
Objective: Develop aircraft operational noise reduction technology to reduce aircraft noise at take-off & approach



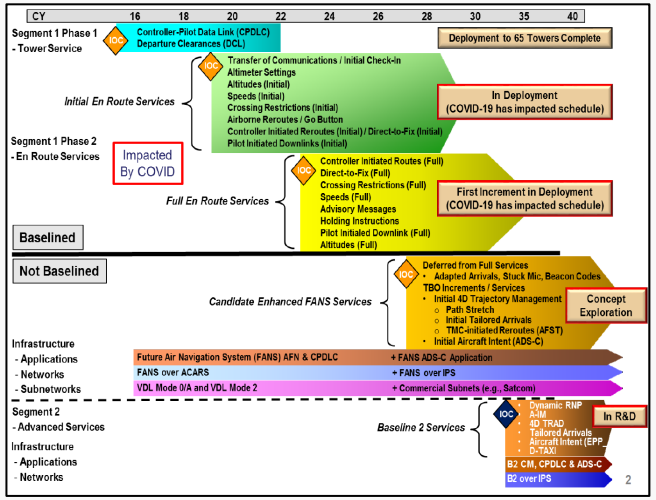
Recent Accomplishments:

(Nov – May)

Initial Design → Design Validation → **Testing & Refinement** → Flight Testing → Reporting

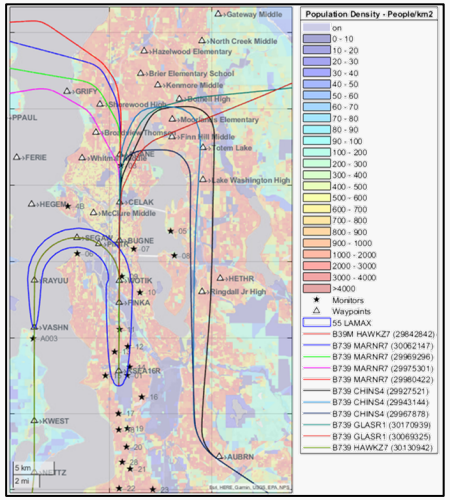


SW Drop 3 – Glasgow Flight Test



FAA Data Comm Coordination

Procedure Optimization & Pilot Simulations



Noise Impact Assessments

Lookahead:

Flight Testing

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Program Summary – 787 ecoDemonstrator

ATP

Today

737 & 787 Flight Demos

Final Report

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- Quiet High Lift
- Intelligent Operations

Design | Fab / Assembly | Flight | Analysis / Reporting

- Next Generation Inlet
- Intelligent Operations

Design | Fab / Assembly | Flight | Analysis / Reporting

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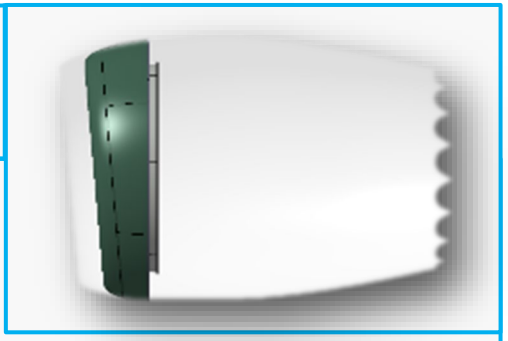
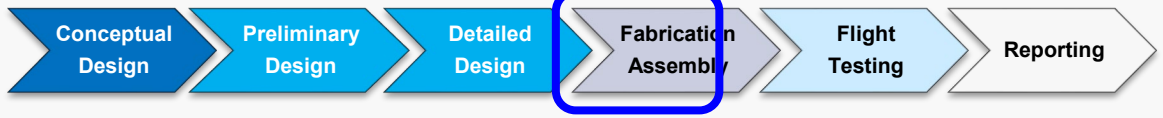
Next Generation Inlet (NGI)

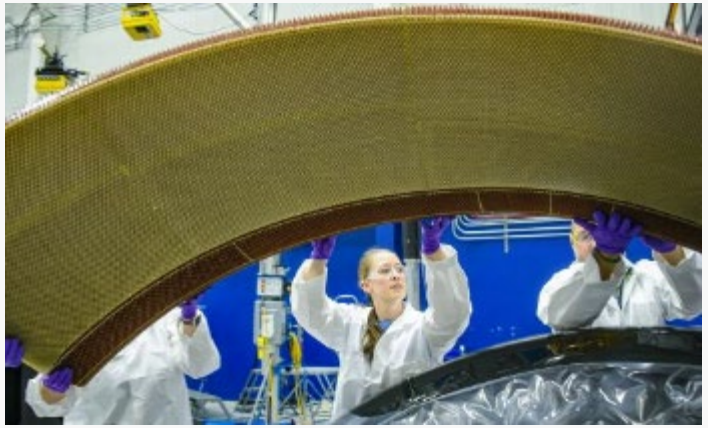
Objective: Develop inlet (engine) technologies to reduce noise at take-off and approach and address reduced-length inlet integration challenges of UHB engines



Accomplishments:

(Nov – May)





Hexcel – Acoustic Core

Post-cure inspections

CLEEN III - NGI Team
(Boeing, Aurora, Hexcel)

Acoustic Inner Barrel
in Autoclave

Lookahead:

Complete Fabrication & Assembly
Flight Testing

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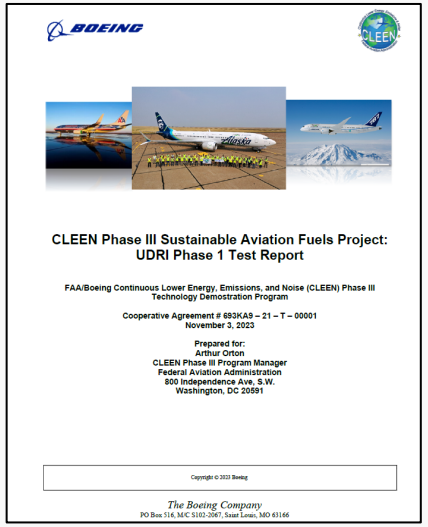
Sustainable Aviation Fuels (SAF)

Objective: Mature fuel system component readiness to enable low aromatic fuels – SAF compatibility

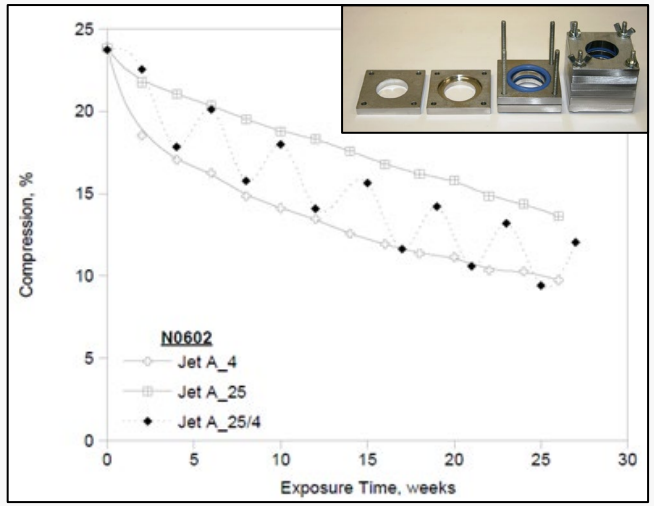
Accomplishments (May – Nov):

(Nov - May)

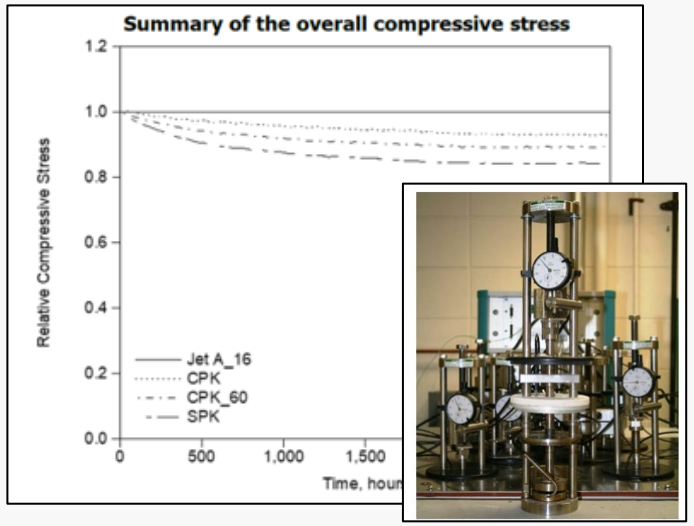
Lab Testing → Reporting



Phase 1 Test Report



Phase 1
Switch Loading



Phase 2
Thermal Cycling

Lookahead:

Complete Phase 2 Lab Test Report – 3Q24
Final Report – 4Q24

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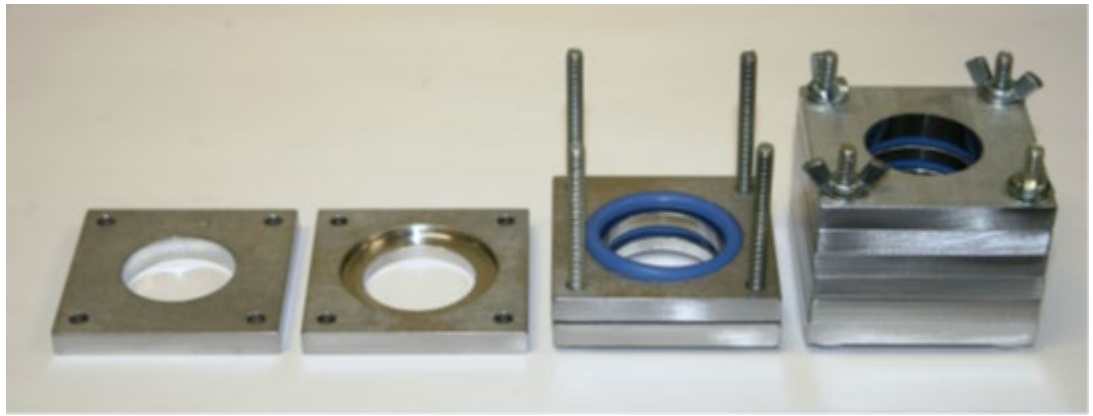
SAF Test Program Overview, Phase 1

Material Selection → **Baseline Testing** → **Accelerated Aging Steady State** → **Accelerated Aging Switch-Loading**

Nitrile Rubber O-rings

Establish Material Properties



Compression set fixtures designed to constrain O-rings in a model gland to mimic the conditions of an internally pressurized seal and produce aged samples

Measure Compression, Compression Set, Volume Swell

Varying Test fluids (Jet A w/25% to 4% aromatics)

Exposure duration: ~ 25 weeks at 160°F

Recondition to eliminate fuel matrix effects

Aged Seals

Exam Material Properties

Measure Compression, Compression, Set, Volume Swell

Switch-loading between Test fluids (high/low aromatics)

Exposure duration: ~ 25 weeks at 160°F

Recondition to eliminate fuel matrix effects

Aged Seals

Exam Material Properties

Results presented in Phase 1 Test Report – Available to the public

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SAF Phase 1 Report

https://www.faa.gov/about/office_org/headquarters_offices/apl/eee/technology_saf_operations/cleen

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Continuous Lower Energy, Emissions, and Noise (CLEEN) Program

The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is the FAA's principal environmental effort to accelerate the develop
Through the CLEEN Pro
industry to expedite int
aircraft. Technologies d
emissions, and use less
Generation Air Transpo
growth.

- Rolls-Royce Low NOx Combustor Final Report
- **Alternative Fuels Reports**
  - GE Sustainable Aviation Fuels Final Report
  - Rolls-Royce Sustainable Aviation Fuels Final Report

CLEEN Phase III Final Reports

- **Alternative Fuel Reports**
  - Boeing Sustainable Aviation Fuels Project - UDRI Phase 1 Lab Test Report

CLEEN Phase III Consortium Meetings

- **November 2023 Consortium Meeting**
  - FAA Office of Environment and Energy R&D Overview
  - America's Phenix Briefing
  - Boeing Briefing
  - Collins Aerospace Briefing

The Boeing Company
Engineering Test and Technology
Boeing Research and Technology

CLEEN Phase III Sustainable Aviation Fuels Project: UDRI Phase 1 Test Report

FAA/Boeing Continuous Lower Energy, Emissions, and Noise (CLEEN) Phase III Technology Demostration Program

Cooperative Agreement # 693KA9 – 21 – T – 00001
November 3, 2023

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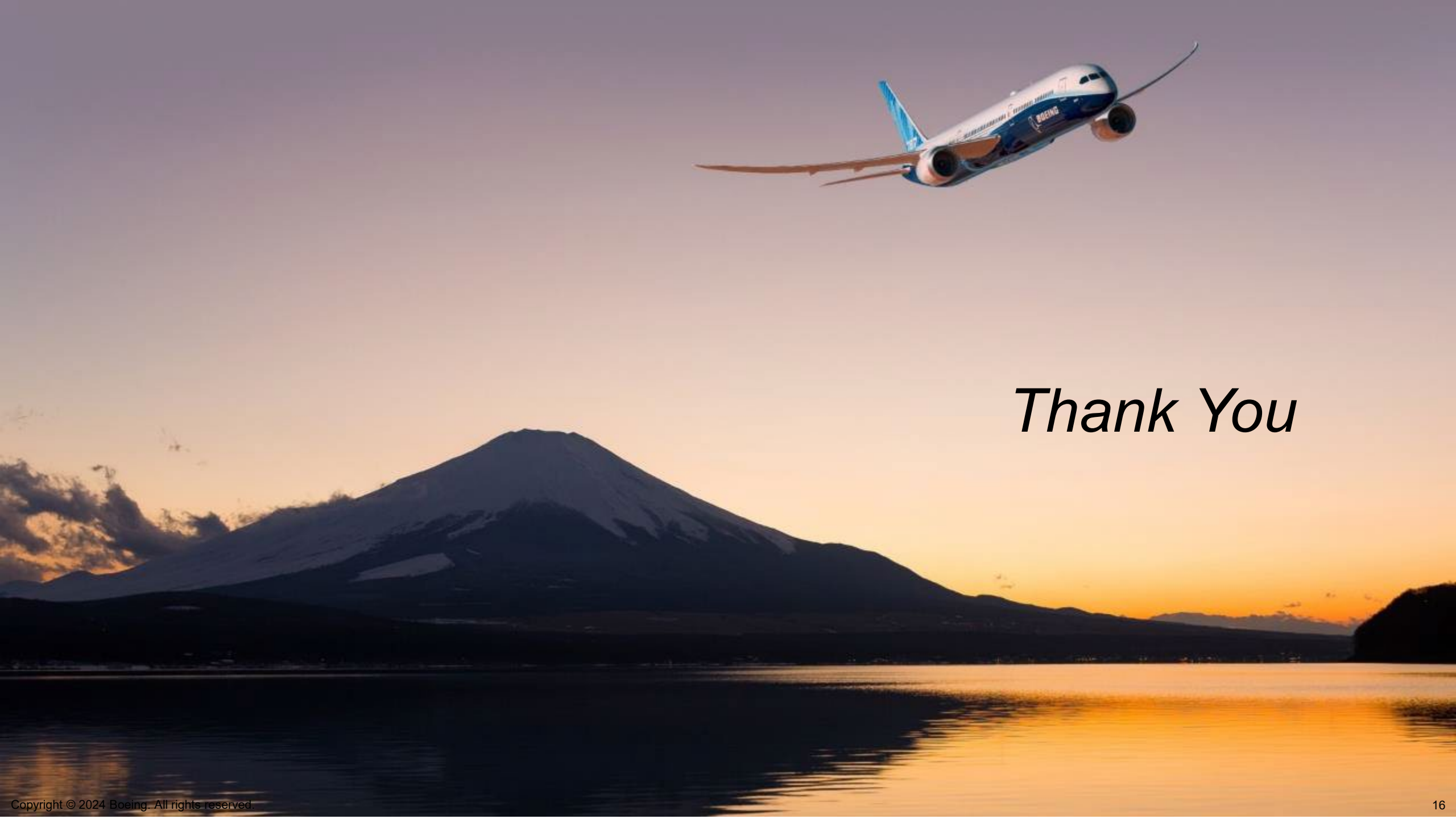

Thank You

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Acronyms

ATP	**Authority to Proceed**
CAA	**Computational Aero-Acoustics**
CFD	**Computational Fluid Dynamics**
dBA	**Decibels, A-weighted**
EPNdB	**Effective Perceived Noise, Decibels**
SAF	**Sustainable Aviation Fuel**
SMA	**Smart Memory Alloy**
UDRI	**University of Dayton Research Institute**
UHB	**Ultra High Bypass**
VG	**Vortex Generators**

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